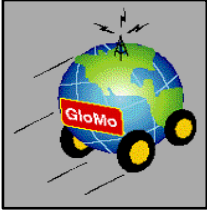

Adaptive Signal Processing & Networking (ASPEN)

George Vardakas
Raytheon Company

***Global Mobile Information Systems (GloMo) Program
Principal Investigators Meeting
March 1, 2000
Hilton Head, South Carolina***



ASPEN Project Team



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Raytheon

System engineering, integration, and test
Network modeling and performance analysis
Wireless node hardware, core software, waveform physical layer

Nokia Wireless Routers

Adaptive link control and channel access
Network protocol (from UCSC/SPARROW program)

Hughes Research Laboratories

Traffic generation models

Purdue University

Adaptive signal processing for spread spectrum networks

University of Michigan

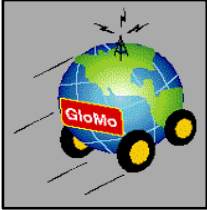
Application of RCPT codes to ARQ protocols in networks

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Project Summary



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An Integrated Solution to Wireless IP Routing with Tactical Multi-channel Software Programmable R

■ **Implementation**

- ▼ 6 wireless nodes, each with 3 wideband transceivers
- ▼ Wireless IP routing and QoS services
- ▼ Link layer channel monitoring and per-packet waveform selection
- ▼ Real-time adaptive modem (transmit power, chips/bit, packet size)

■ **Modeling & Simulation**

- ▼ CPT for evaluation of medium-sized networks with 'target' software
- ▼ Low-Fidelity OPNET model for large network performance evaluation
- ▼ Development of video, web, and aggregate traffic flow models for realistic characterization of traffic dynamics

■ **Research**

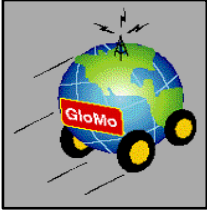
- ▼ Application of rate compatible punctured turbo codes to ARQ protocols in DS-CDMA networks
- ▼ Application of adaptive signal processing techniques (e.g., interference excision and multipath combining) to networks of software radios

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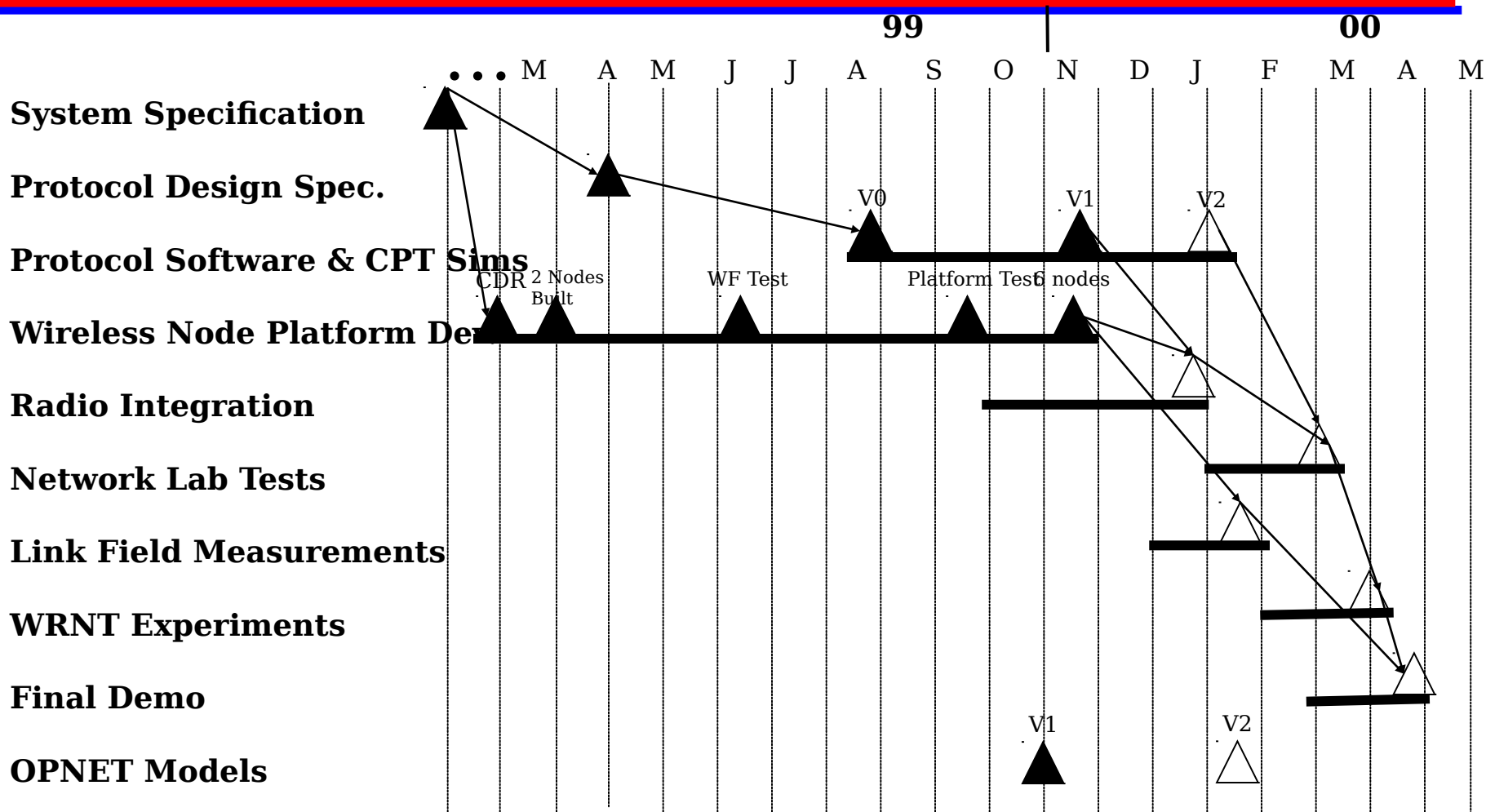
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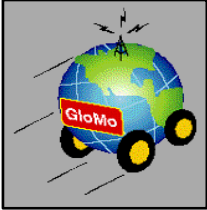


ASPEN Project Milestones



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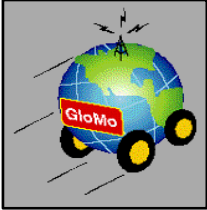


ASPEN Network Services



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- **Multicast (no acks) for Situation Awareness Dissemination**
 - ▼ IP multicast using CAMP
 - ▼ Multiple groups can be set up with SA servers as in Tactical Internet
 - ▼ Includes wide-area broadcast of alerts and warnings
- **Reliable Multicast (positive acks)**
 - ▼ Reliable CAMP
 - ▼ Several groups for C2 mission planning and Air Task Orders
 - ▼ Tend to be large messages that are not latency-sensitive
- **Unicast Datagrams**
 - ▼ Routed using IP/STAR
 - ▼ IP TOS field used to request link layer ack services (priority queuing, waveform mode selection)
 - ▼ Symmetrical and Asymmetrical data between two nodes for internet services, voice, and C2 traffic
- **Reservation Protocol**
 - ▼ Reserved bandwidth for real time, delay/jitter-sensitive communications

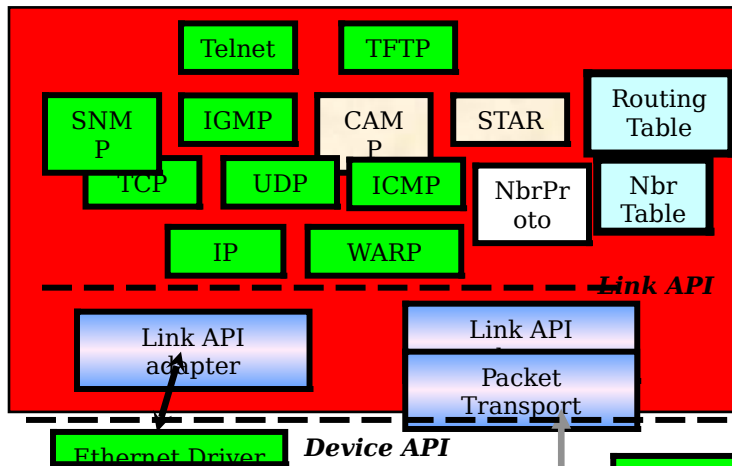


Networking Protocols

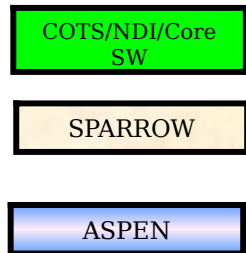


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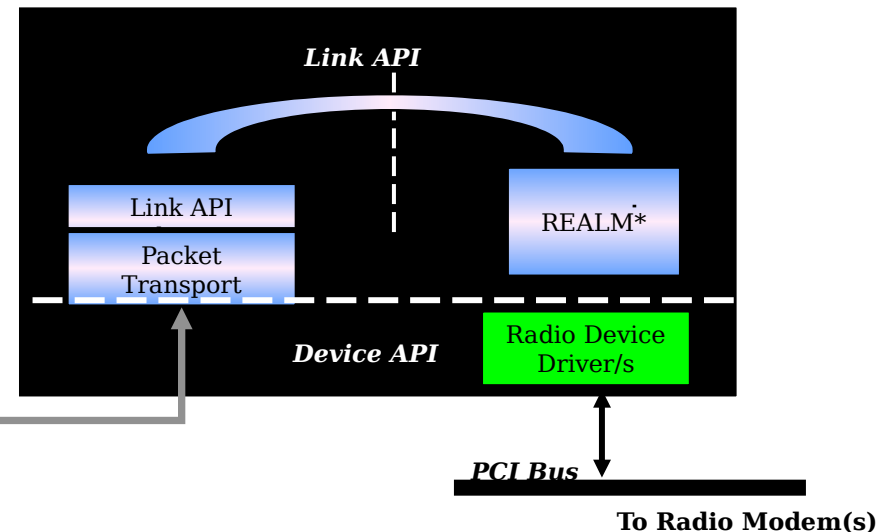
RED PROCESSOR

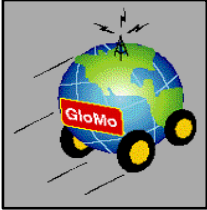


Legend:



BLACK PROCESSOR



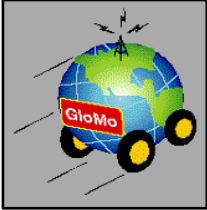


Overview of REALM



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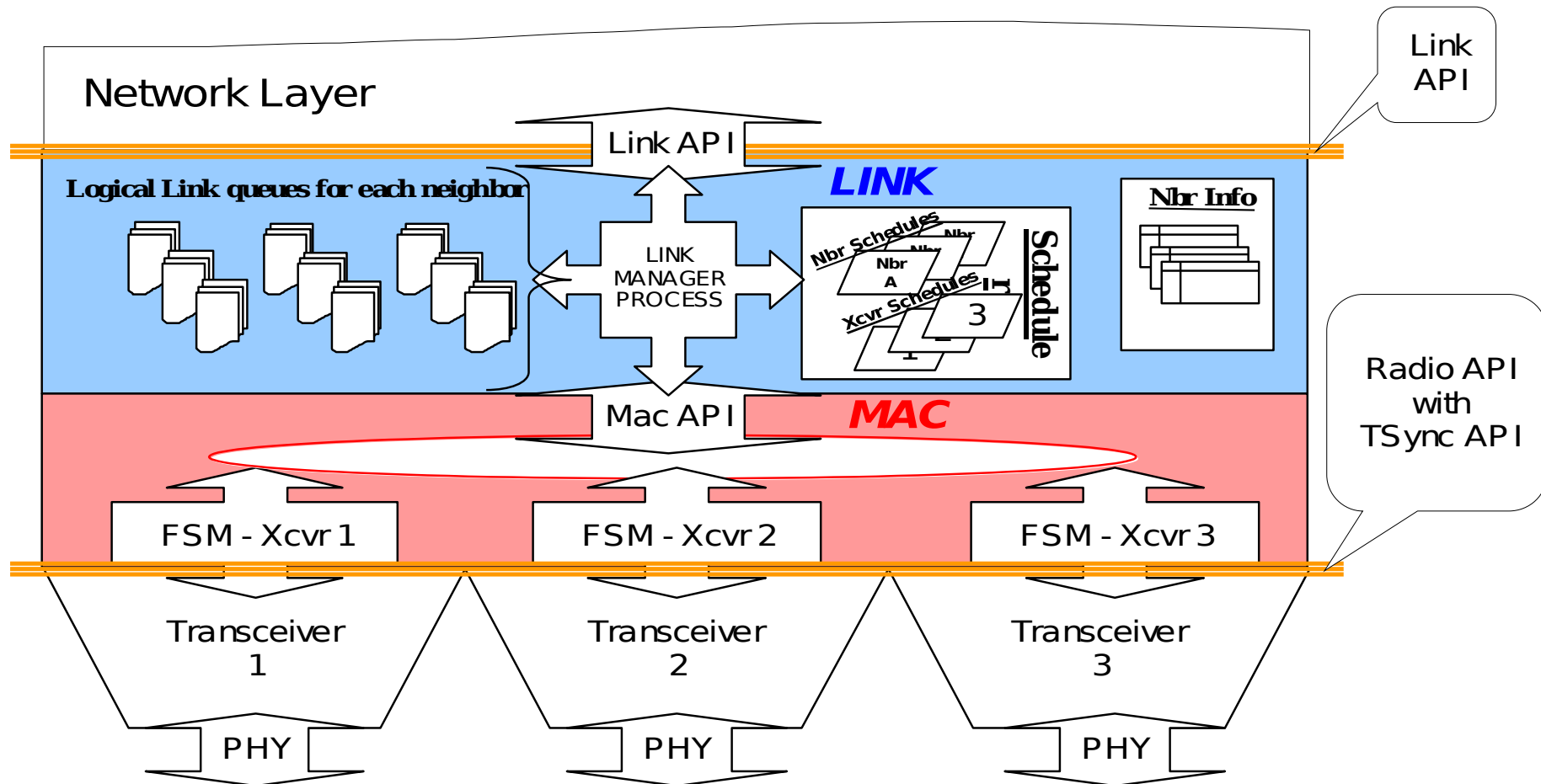
- Multi-Channel, Reliable Media Access Protocol
- MAC-Layer, Common Channel Congestion Avoidance
- Link-Layer Pacing and Flow Control
- Rapid/Efficient Link-Layer Acknowledgments.
- Multiple co-operative/co-located transceivers
- Adaptive, dynamic scheduling of control packets
- Multiple transceiver operation (e.g., co-located transceivers)

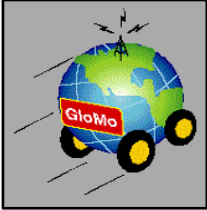


REALM Architecture

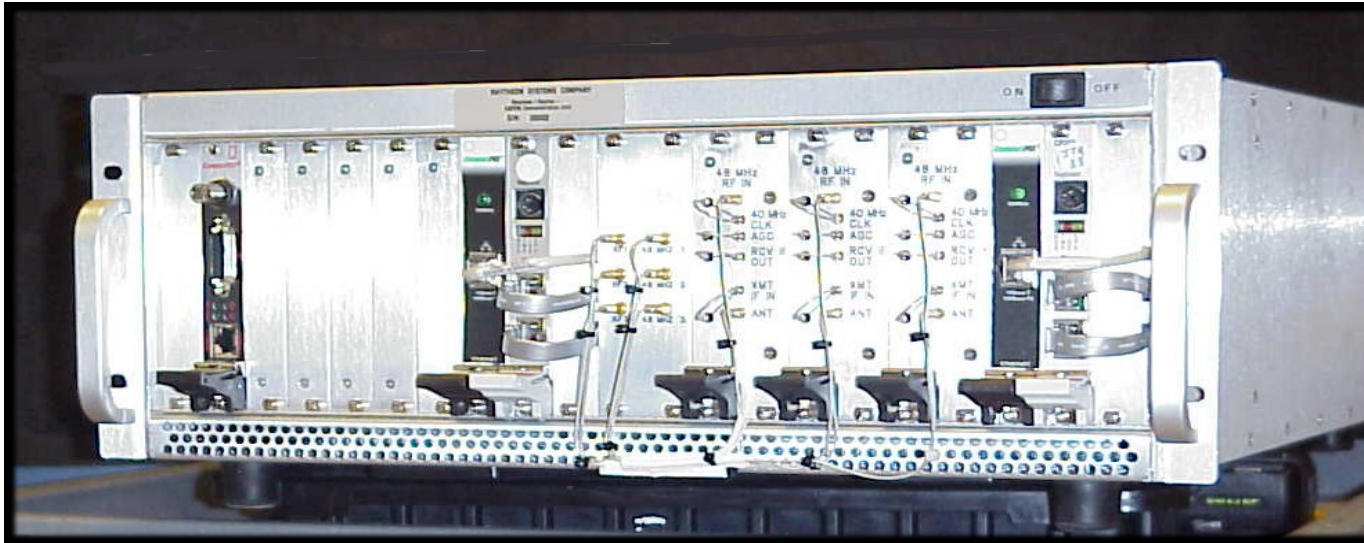


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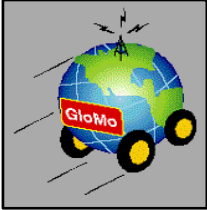




ASPEN Lab Prototypes



- Hardware built for 6 wireless nodes
- Each node consists of 3 wideband channels
- RF range from 225 MHz to 1000 MHz
- High Speed Wideband Modem with a spread spectrum rate of 20 MCPS and user data rates up to 800 kbps per channel



OPNET Simulation



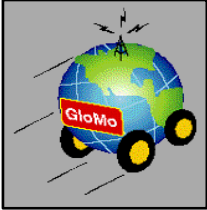
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■ Objectives

- ▼ Develop low fidelity OPNET models for
 - ▼ Neighbor (Nbr)
 - ▼ Link/MAC (REALM)
 - ▼ Radio model (three transceivers in ASPEN)
- ▼ Integration with SPARROW models (STAR, CAMP, IP)
- ▼ Integration with SEAMLSS-lite

■ Status

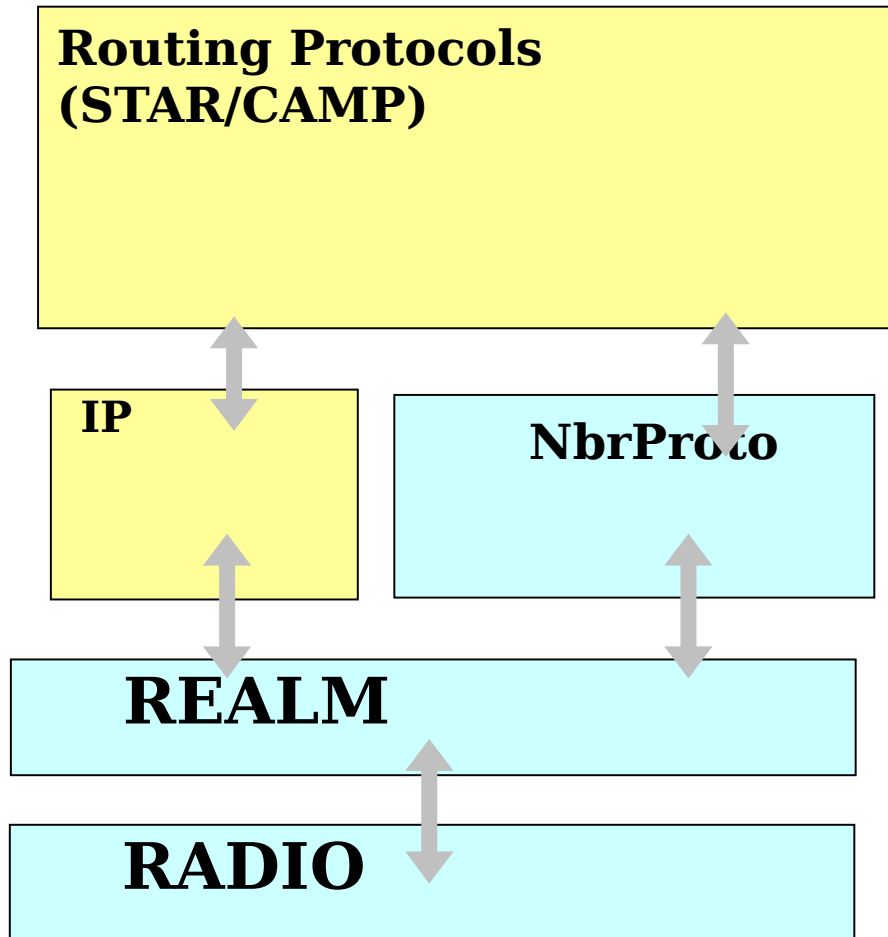
- ▼ 6-node simulation complete
 - ▼ Alpha version of REALM, with STAR and CAMP
- ▼ REALM Model enhancements being developed
 - ▼ Waveform selection, Power control, Reservations
- ▼ Model integration in March
 - ▼ New version of SPARROW protocols
 - ▼ SEAMLSS-lite



OPNET Simulation



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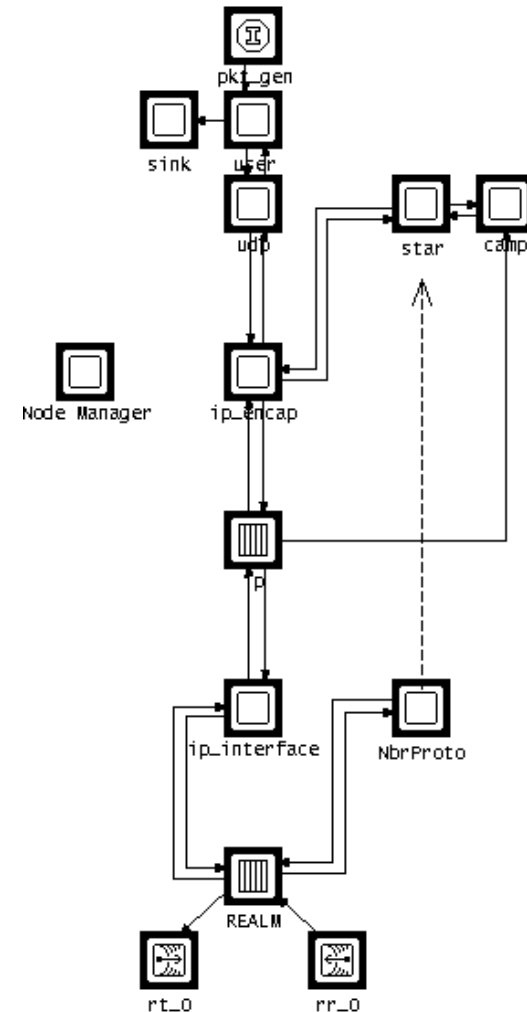
SPARROW

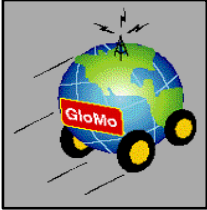
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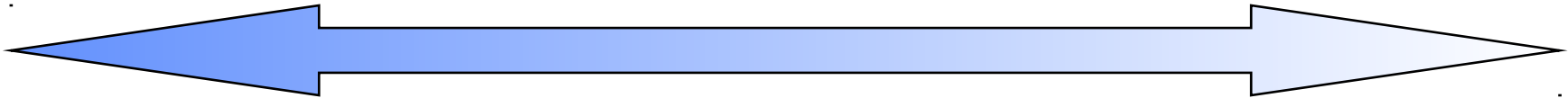
Levels of Fidelity



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High Fidelity

Low Fidelity

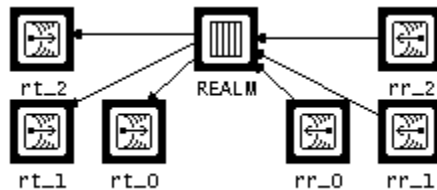


Longer Execution time

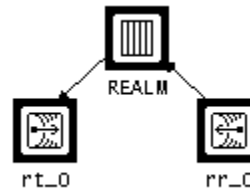
Shorter Execution time

CPT sim

OPNET
3 transceiver



OPNET
1 transceiver

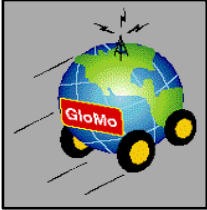


OPNET
0 transceiver



Analytical

- Run-time in wireless simulation highly dependent on RF pipeline stages
 - ▼ Each is potential receiver (requires pipeline calculation)
 - ▼ Decreasing the number of pipeline calculations substantially decreases run-time

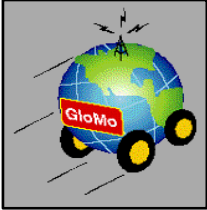


Radio Model



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- Multi-Transceiver
 - ▼ Multi-transceiver with frequency selection
 - ▼ Most faithful representation
 - ▼ 3x pipeline calculations per node
- Single transceiver model
 - ▼ Increase number of timeslots and data rate to match multi-channel.
- Zero transceiver model
 - ▼ Characterize REALM behavior
 - ▼ HRL trace analysis of higher fidelity simulations
 - ▼ REALM behavior model
 - ▼ Effect 'live' traffic appropriately
 - ▼ Fastest run-time

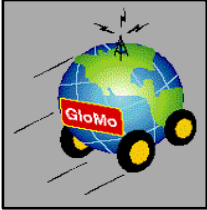


Calibration



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- OPNET and CPT
 - ▼ High fidelity CPT simulations provide results for comparison.
 - ▼ Delay, throughput
 - ▼ Adapt OPNET model parameters to get similar results
- Link tests with ASPEN modem
 - ▼ Propagation distances as function of waveform
 - ▼ C/No measurements
- Four node lab test
 - ▼ Setup simulation to emulate lab configuration



Traffic Modeling Status



Trace Collection

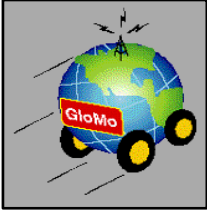
- ▼ Ongoing WAN traffic collection at HRL labs (tcpdump, WINS-net router)
- ▼ Next: SEAMLSS simulation trace collection

Mathematical Analysis & Models Development

- ▼ Developed analysis and validation tools:
 - ▼ Wavelet transform, multifractals, periodogram, variance-time

Traffic Generators

- ▼ Developed Traffic generators that are easily transportable/integrable
 - ▼ Multifractal, fractional Gaussian noise, Markov-Renewal Process, M/Pareto
- ▼ Next: Integration of models to network simulation testbed (OPNET/SEAMLSS-lite)



Adaptive Signal Processing

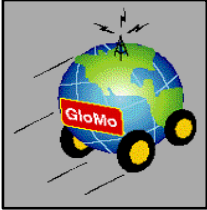


▼ *Allocation of Multicarrier CDMA Using a Signal Subspace Approach:* A subspace-based channel estimation technique is being developed to obtain the required information. Numerical results are showing that the proposed algorithm is robust to fading and the near-far problem.

▼ *Transmitter Signal Optimization:* Optimum chip waveforms are being found for the excess bandwidth and are shown to achieve the minimum average bit error probability

▼ *Reducing Co-Channel Interference:* Preliminary performance analysis shows that two users can be easily accommodated in a single-user channel with slight degradation of bit error rate

▼ *Receiver Optimization:* Investigating the error probability of a correlation receiver as the chip waveform is adapted depending on the energy and delay profiles of interfering users.



Adaptive Coding



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- Maximum Network Throughput Under Energy Constraint
 - ▼ Simulation results indicate inverse linear relationship between energy constraint and maximum throughput for BPSK, MPSK, and MQAM modulations
 - ▼ Relationship proven mathematically
- Joint Optimization of Rate and Spreading Gain
 - ▼ Using MPSK and MQAM modulation and coherent demodulation, with moderate alphabet size and small code rate, can obtain near limit throughput